FACILITY HAZARD CATEGORIZATION REVIEW

FOR

BROOKHAVEN LINAC ISOTOPE PRODUCER

AUGUST 1998

Prepared By ____________________ 8/25/98
S. H. Moss, Nuclear Safety Officer - WMD — Date

Reviewed By Dr. Kathryn Kolsky 8-26-98
Dr. K. L. Kolsky, Radiochemistry Coordinator — Date

Approved By Leonard F. Mausner 9/3/98
Dr. L. F. Mausner, BNL Facility Manager — Date

BROOKHAVEN NATIONAL LABORATORY
BROOKHAVEN SCIENCE ASSOCIATES
Under Contract No. DE-AC02-98CH10886 with the
UNITED STATES DEPARTMENT OF ENERGY

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I. EXECUTIVE SUMMARY

Facility Mission

The Brookhaven LINAC Isotope Producer (BLIP) is presently managed by the Radionuclide and Radiopharmaceutical Research Group of the Medical Department. The BLIP takes spare pulses of 200 MeV protons from the LINAC and directs them to specially prepared targets for nuclear medical purposes. The major purpose of this program is to carry out research on radioisotopes for use in the design, development, and evaluation of new and more specific radiopharmaceuticals for both diagnostic and therapeutic applications. The program provides for the distribution of isotopes for offsite sale, primarily to the nuclear medical community, for both diagnostic and therapeutic purposes. The activities conducted in the BLIP are integral to the research and production of radionuclides required for this work. (Specific isotopes are generated by the irradiation of prepared targets at the BLIP with subsequent transfer to and separation processing at the TPL - a two step process involving both facilities).

This document is being prepared to justify the retention of the Radiological Facility classification (below Non-reactor Nuclear Hazard Category 3), while resuming the irradiation of targets creating Xe-127 at the BLIP at a rate of up to 4 Ci / Month.

Location

The BLIP is located within Buildings 931 A, B, and C at the end of the AGS LINAC, on the western side of Brookhaven National Laboratory (BNL) in Upton, New York. (See Figure I-1 for location of Bldgs 931A/B/C with respect to BNL Site Plan and Figure II-1 for the layout of the BLIP within Bldgs 931A/B/C). The three buildings contain; the BLIP tank and hotcell, the computer and operations console, and enclosed handling area for forklift and transport pig. This does not include the "BLIP pump house", located on top of the LINAC berm, which contains cooling apparatus for the BLIP beam line magnets, as well as cooling equipment for the AGS Booster beam stop. The AGS Department has sole responsibility for the operation, maintenance and safety of this equipment. Accordingly, the pump room is not considered in this document.

Furthermore, the operation, maintenance, access security and safety of the BLIP beam line is an AGS responsibility. BLIP has NO control over delivery of beam except for shut-off. Access to the BLIP beam line is through a concrete plug door and two gates, all of which are interlocked with the AGS security system. These items are covered in the AGS Safety Implementation Plan and the AGS SAR.

Life Cycle Phase

DOE-STD-1027-92, Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports, discusses the importance of defining a facility's stage in its life cycle in order to determine the appropriate amount of rigor (graded approach) required for its Safety Analysis. Among the various life-cycle stages mentioned are: new facility seeking permission to operate; established facility seeking authorization to continue operations; facility near the end of its operating life and unlikely to be modified before retirement; facility near the end of its operating life which may be modified or extended in the future; facility which is partly shutdown and only used for limited functions; and facility approaching decommissioning.

Based upon the following chronology, this facility (BLIP) is judged to be an established facility seeking authorization (confirmation of current classification as a Radiological Facility) to continue operations.

Year	Activity
1972	BLIP Commissioning: BLIP was built and commissioned with a Safety Analysis Report (SAR) in 1972 as the world's first facility to demonstrate the capability of a large proton LINAC for efficient medical radionuclide production of difficult-to-make, medically useful radionuclides [Richards et al., 1973]. Building 931 contained two rooms (Rms.) 931A and 931B. The BLIP target irradiation occurred in Rm 931A and the other room, 931B, was owned by the Chemistry department. In 1973, the TPL was not in existence.

Processing of BLIP targets occurred in laboratories in Rms. 66, 66A, and 54 in Bldg. 801. Rm. 66 contained one processing hot cell and four processing hot boxes, Rm. 66A contained the entrances to the processing hot cell, and Rm. 54 contained two caves of stacked lead brick for processing. The facilities in Bldg. 801 were present prior to the commissioning of BLIP. In 1973, these facilities and BLIP were part of the Department of Applied Science. In 1977, they were transferred to the Medical Department. The medically important isotopes ^{123}I, ^{81m}Kr, ^{52}Fe, and ^{127}Xe were routinely produced with these facilities.

1984 <u>BLIP Facility Upgrade:</u> Several serious technical problems, coupled with an overall decline in reliability motivated the target irradiator facility upgrade effort. Years of operational experience at high beam current and high radiation levels suggested many desirable improvements to the facility. The facility was renovated to: (a) permit safe repair or replacement of all radioactive components; (b) reduce target holder insertion or removal time to less than 1 min; (c) reduce personnel radiation exposures while safely handling target activities of up to 1,000 Ci; and (d) install a computerized control and monitoring system for unattended operation. More details are given in [Mausner, *et al.* 1989]. At this time, radionuclides such as ^{28}Mg, ^{67}Cu, ^{82}Sr, ^{68}Ge, ^{123}I, ^{81m}Kr, ^{52}Fe, and ^{127}Xe , were in routine production. A new SAR was written for the BLIP facility at this time.

1995 <u>BLIP Upgrade and TPL Commissioning:</u> The BLIP Facility was further upgraded to respond to a mounting national need for a continuous and reliable source of isotopes. The target cooling system was upgraded and automated, the targets and target mechanical systems were replaced with a more robust design, and the control system was upgraded. Also, shielding was enhanced to increase personnel safety especially with respect to very penetrating high energy neutrons created by proton spallation reactions in the targets and structural supports. All computer control system equipment was moved into Rm. 931A.

The SAR was modified to reflect these changes. Further details are given in [Mausner and Alessi, 1997]. Processing facilities in Bldg 801 were also upgraded. Rm. 54 was removed from service and all isotope processing activities were concentrated in Rms. 66, 66A. Two additional processing hot boxes were installed in Rm. 66 and HEPA filtered hot box/hot cell ventilation was upgraded. A fume hood was installed at the end of the hot boxes with the porthole entrances to the hot boxes contained within. In Rm. 66A, shielded doors were installed for personnel access to hot cell 1. The TPL was commissioned at this time and a Safety Assessment Document (SAD) was written and approved by BNL Management. The radionuclides presently (1995) produced at BLIP are ^{7}Be, ^{28}Mg, ^{67}Cu, ^{68}Ge, ^{82}Sr, and $^{95m,96}Tc$.

1998 Building 801 Upgrade: Various improvements were made to Bldg. 801, including the TPL. Specific improvements which affected the TPL were the following: (a) Install secondary containment in the D-waste lines that handle low level radioactive aqueous non-hazardous waste; (b) Build a high level radioactive aqueous neutralization and solidification system to handle aqueous effluent from the hot cell/hot boxes; (c) Convert Rms. 54, 55 into an addition to Rm. 66 with two new hot boxes; and (d) Install new fresh air ventilation system for “hot area” (including TPL).

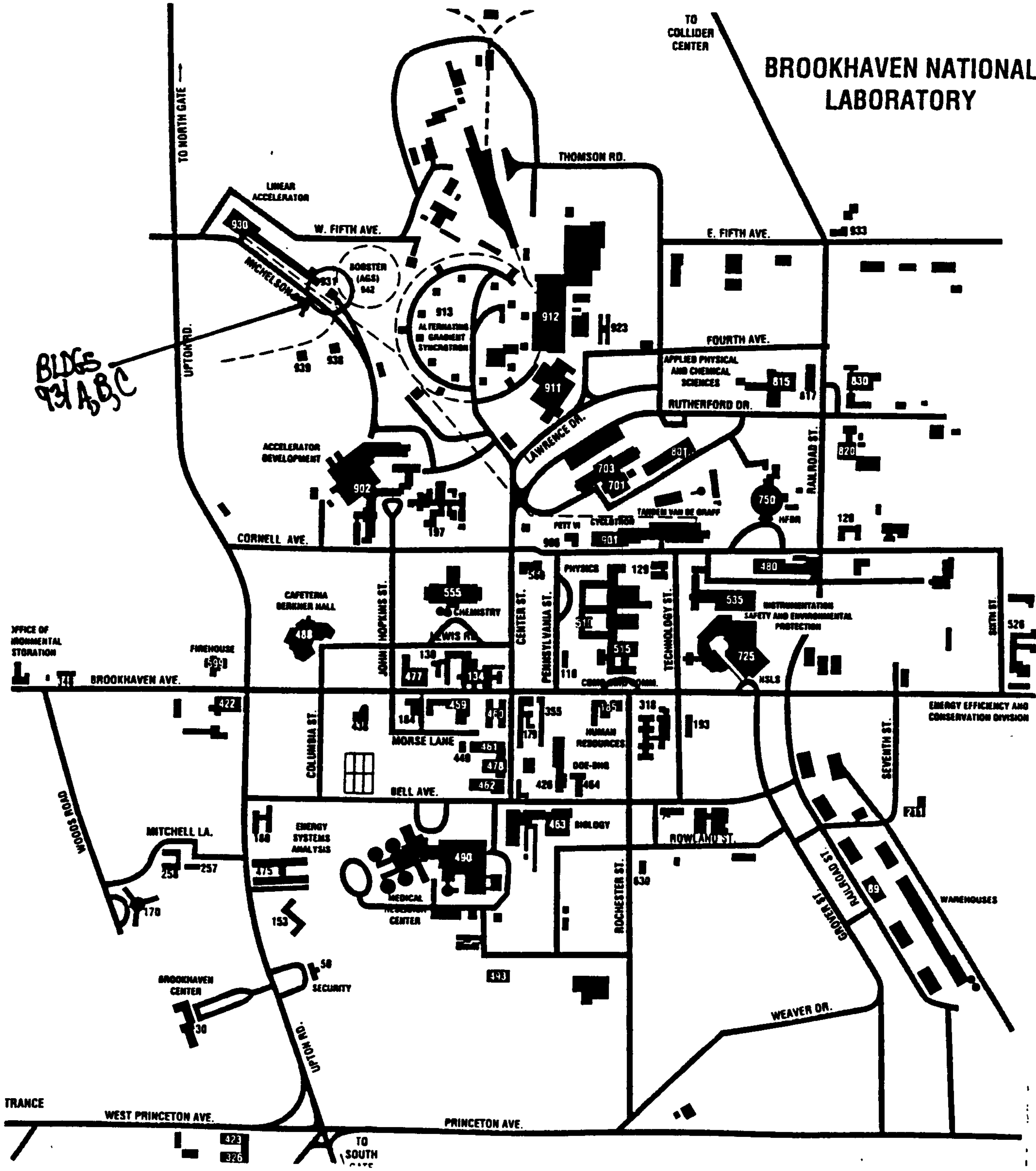
Hazard Class

The hazard class of this facility, as defined by the Preliminary Hazard Analysis for BLIP/Building 801 Upgrade, dated September 1994, was that of “Radiological Facility” and “Low Risk”. This classification was confirmed by the Safety Assessment Document for the Brookhaven LINAC Isotope Producer, dated March 1996. It is reconfirmed here by the following analytical review and in consideration of the renewed irradiation of targets for the production of Xe-127 at the facility.

Segmentation Plan

No change to the segmentation plan presented within the approved Safety Assessment Document for the Brookhaven LINAC Isotope Producer dated March 1996, is contemplated herein.

Figure I-1


BROOKHAVEN NATIONAL LABORATORY
TO COLLIDER CENTER
TO NORTH GATE
LINEAR ACCELERATOR
930
W. FIFTH AVE.
MICHELSON
BOOSTER (AGS) 942
931
BLDGS 931 A,B,C
913
ALTERNATING GRADIENT SYNCHROTRON
THOMSON RD.
912
923
911
E. FIFTH AVE.
933
FOURTH AVE.
APPLIED PHYSICAL AND CHEMICAL SCIENCES
815
817
830
RUTHERFORD DR.
UPTON RD.
539
538
ACCELERATOR DEVELOPMENT
902
LAWRENCE DR.
801
703
701
750
HFBR
RAILROAD ST.
820
197
TANDEM VAN DE GRAAFF
901
CORNELL AVE.
480
CAFETERIA BERKNER HALL
488
555
CHEMISTRY
LEWIS RD.
PHYSICS
129
535
INSTRUMENTATION SAFETY AND ENVIRONMENTAL PROTECTION
725
NSLS
526
FIREHOUSE
JOHN HOPKINS ST.
CENTER ST.
PENNSYLVANIA ST.
TECHNOLOGY ST.
510
515
130
477
134
BROOKHAVEN AVE.
422
459
460
355
318
193
ENERGY EFFICIENCY AND CONSERVATION DIVISION
MORSE LANE
461
478
462
179
HUMAN RESOURCES
DOE-BHG
464
426
COLUMBIA ST.
BELL AVE.
SEVENTH ST.
WOODS ROAD
MITCHELL LA.
ENERGY SYSTEMS ANALYSIS
463
BIOLOGY
ROWLAND ST.
258
257
475
490
MEDICAL RESEARCH CENTER
630
ROCHESTER ST.
RAILROAD ST.
GROVER ST.
WAREHOUSES
170
153
58
SECURITY
BROOKHAVEN CENTER
30
493
WEAVER DR.
UPTON RD.
TRANCE
WEST PRINCETON AVE.
PRINCETON AVE.
423
326
TO SOUTH

II. INTRODUCTION

In the early 1970's, the Alternating Gradient Synchrotron (AGS), which was operating as the principal accelerator at BNL, was modified in several ways to improve its performance. One phase of the improvement was to replace the 50 MeV Linear Accelerator (LINAC) with a new 200 MeV LINAC. Each AGS cycle the LINAC produces more pulses than are needed for AGS injection. It was decided to utilize some of the extra pulses in a facility called the Brookhaven LINAC Isotope Producer (BLIP). In this device the 200 MeV protons are used to bombard targets of selected materials to produce radionuclides for medical use.

The BLIP Facility is part of the Medical Department and is located on the western side of the BNL site at the end of the AGS LINAC (see Figure I-1). The Facility includes three buildings (931A, 931B and 931C). One is the primary location for the BLIP tank and Hot Cell. The second building, which was originally an irradiation facility for the Chemistry Department, was incorporated into the BLIP complex and contains the computer and the operations console behind the separating wall between the two buildings. The third building, the latest addition, creates enclosed access between the other two buildings and provides enclosed cover for the forklift which handles the lead transport pig (see Figure II-1).

This does not include the "BLIP pump house", located on top of the LINAC berm, which contains cooling apparatus for the BLIP beam line magnets, as well as cooling equipment for the AGS Booster beam stop. The AGS Department has sole responsibility for the operation, maintenance and safety of this equipment. Accordingly, the pump room is not considered in this document. Furthermore, the operation, maintenance, access security and safety of the BLIP beam line is an AGS responsibility. BLIP has **NO** control over delivery of beam except for shut-off. Access to the BLIP beam line is through a concrete plug door and two gates, all of which are interlocked with the AGS security system. These items are covered in the AGS Safety Implementation Plan and the AGS SAR.

The BLIP is presently managed by the Radionuclide and Radiopharmaceutical Research Group of the Medical Department. The major purpose of this program is to produce radioisotopes and to use these products in the design, development, and evaluation of new and improved radiopharmaceuticals for both diagnostic and therapeutic applications. The primary program provides for the production, processing and distribution of isotopes for offsite sale to the nuclear medical community. The activities conducted in the BLIP are integral to the research and production of radionuclides required for this work.

The removable radiological material inventory for the BLIP has always been well below the DOE-STD-1027-92 Threshold Quantities for compliance with DOE Order 5480.23 (See Table 1 in Section IV - Analysis, for historical maximum radiological material inventory spreadsheet, basis for BLIP categorization as below Nonreactor Nuclear Hazard Category 3, or "Radiological Facility").

The re-examination of the Threshold Quantities for confirmation of the Radiological Facility categorization of the BLIP is predicated upon the need to again produce Xe-127 as one of the radioisotopes regularly made available through the Radionuclide Research Production Program at BNL. (See Appendix A for a copy of the DOE Program Office Letter of Request.)

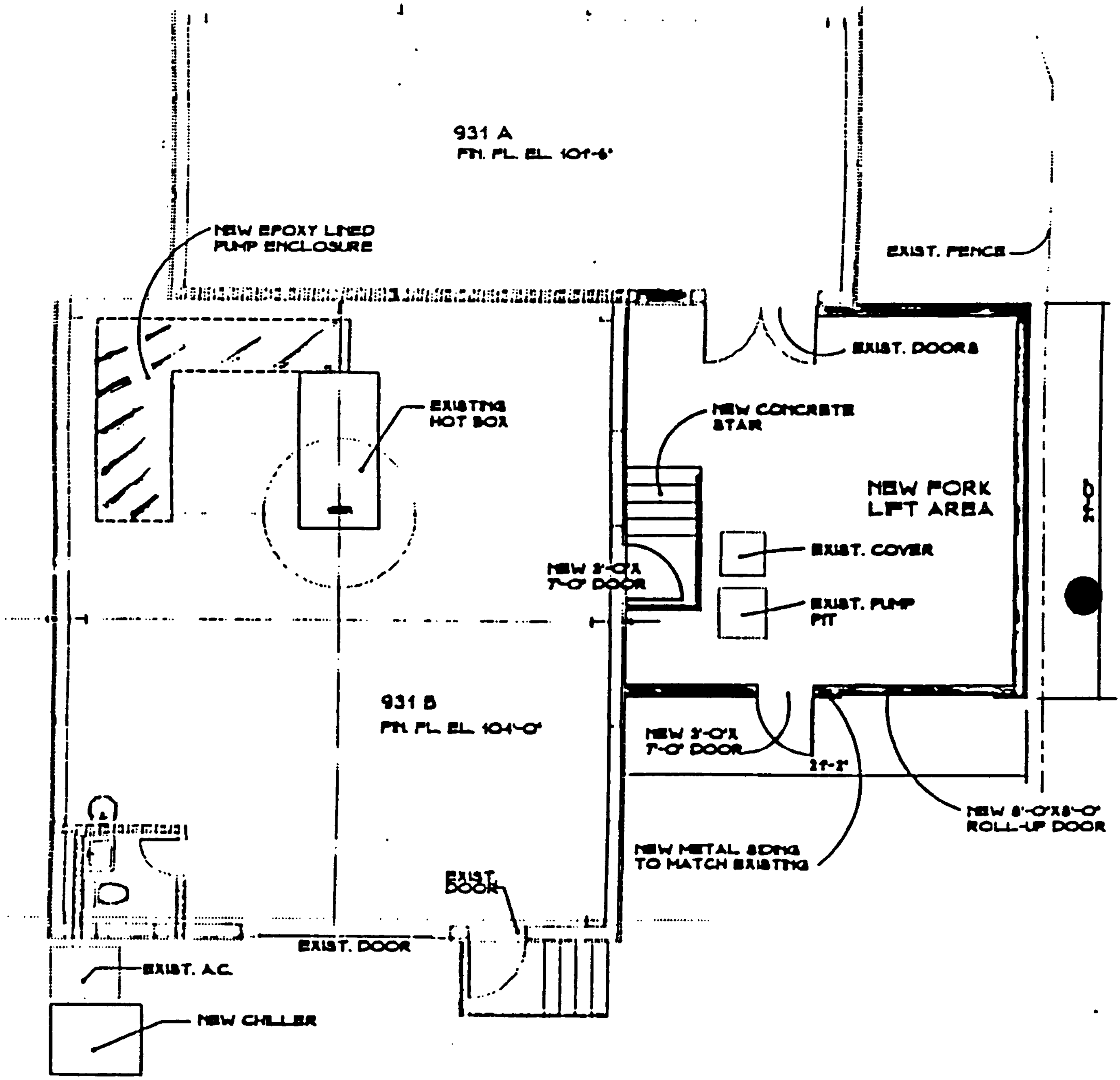
Xe-127 [$T_{1/2}$ = 36.3 days, E_γ = 202.9 KeV (68%), 172.1 KeV (25%)] was originally developed at BNL in 1973 for lung imaging using SPECT (Single Photon Emission Computerized Tomography) for patient work-up and management of pulmonary embolism and black lung disease. This radionuclide offered the advantage of lower radiation dose to the patient and superior resolution images over Xe-133, the prior standard. Xe-127 was widely distributed through Mallinckrodt Medical during the 1980s as a Food and Drug Administration (FDA) approved agent for SPECT imaging. Due to a variety of reasons, the demand declined substantially in the early 1990s and its production at BNL ceased in 1992. However, a recent surge of interest in using Xe-127 for absolute cerebral blood flow measurement and imaging using

SPECT has occurred and the nuclear medicine community has petitioned the DOE Office of Medical, Industrial, and Research Isotope Supply (MIRIS) to develop the isotope for production and sale. MIRIS has, in turn, requested that the Radionuclide Research/Production Program at BNL [comprised of the Brookhaven LINAC Isotope Producer (BLIP) and Target Processing Laboratory (TPL)], carry out this development task.

Xe-127 is produced at BLIP by irradiating CsCl targets with 192 MeV protons, using the reaction ^{133}Cs (p, 2p5n) ^{127}Xe. Theoretical calculations have shown that various radioisotopes of Iodine are co-produced in these targets via ^{133}Cs (p, 3pXn) reactions. It is anticipated that up to four (4) Curies/month of Xe-127 would have to be produced and distributed to meet the needs of the nuclear medicine community. Since the isotope was produced using the same production reaction and a similar processing scheme for 20 years (1973 - 1992), the program has extensive experience handling this type and amount of radioactive material (including well-established procedures, training, Facility Support [HP] coverage, knowledge and historical data). The hazards are known and well understood. The production and processing scheme has also recently been reviewed by the Medical Department Experimental Safety Review Committee (Experimental Safety Review ESR 97-03 attached as Appendix B). All comments provided by the Medical Department Experimental Safety Review Committee will be addressed before the production of Xe-127 begins. Comment #7, for example, is being addressed by submission of this document to DOE-BHG for approval.

Even though extensive prior experience exists in the production and handling of Xe-127 at the BLIP, prior to full production runs [Xe-127 @ 4 Ci], a graduated series of test runs will be carried out. This would re-confirm the theoretical calculations of all the ancillary radio-isotopes to be produced in concert with Xe-127 and update the experimental experiential data.

Figure II-1



BUILDING 931A,931B

III. ASSUMPTIONS

ASSUMPTION #1 : The theoretical numbers for isotope production during the Xe-127 runs are fundamentally accurate (will be re-confirmed via a series of graduated test runs in preparation for full production runs).

ASSUMPTION #2 : All of the assumptions included as part of the approved Safety Assessment Document for the Brookhaven LINAC Isotope Producer, dated March 1996, are also invoked here.

ASSUMPTION #3 : The ratioing of the Airborne Release Fractions as taken from DOE-STD-1027-92 Change 1 and DOE-HDBK-3010-94, Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities, Vols. I and II, represents a reasonable approach to correct for the overly conservative and restrictive categorization based upon the rote application of the Table A.1 Thresholds for Radionuclides as taken from Attachment 1 of DOE-STD-1027-92, Change 1.

IV. ANALYSIS

DOE Order 5480.23, Nuclear Safety Analysis Reports, requires hazard categorization for all DOE nuclear facilities. Facilities in this case includes; not only physical facilities, but also projects, operations and activities. In accordance with DOE Order 5480.23, the hazard categorization may be used as a means of approximating the magnitude of unmitigated hazards inherent to a facility or activity. To that end, the hazard categorization may be used as one input when applying the "graded approach" to a DOE nuclear facility's conduct of safety analysis (e.g., specification of the safety analysis' appropriate scope, level of formality and rigor, etc.).

Both DOE-STD-1027-92 and DOE-EM-STD-5502-94, Hazard Baseline Documentation state that a Safety Analysis Report (SAR) is not required if a facility or activity is less than Category 3. Furthermore, DOE-STD-1027-92 was originally intended to classify fuel fabrication, weapon materials processing facilities, and nuclear reactors that contain hazardous materials that are in different chemical and physical forms, possess different airborne release characteristics, and contain processes that are much more energetic by nature, than those available at the BLIP. Consequently, rote application of DOE-STD-1027-92's guidance may lead to an overly conservative hazard categorization for the BLIP that would have an adverse impact on the research work to be accomplished there. These impacts would greatly increase costs by mandating upgraded safety basis documentation, higher levels of quality assurance, greater legal liabilities with little or no value added.

DOE-STD-1027-92 prescribes an approach for the preparation of hazard categorization that meets the requirements contained within DOE Order 5480.23. In accordance with these requirements; nuclear facilities are categorized as either Category 1, 2, 3, or below Category 3 (also known as Radiological Facility - the present categorization at BLIP). For determination of Category 2 and 3 facilities, DOE-STD-1027-92 relies on a table of radiological inventory based Threshold Quantities (TQs). In general, these Threshold Quantities are back calculated from assumed hypothetical dose consequence values of 1 Rem at a 100 meter distance and 10 Rem at a 30 meter distance for Category 2 and 3 facilities, respectively. These TQs are contained in Attachment 1, Table A.1 to DOE-STD-1027-92.

Associated with the Threshold Quantities as part of the back calculation from the dose limits are parameters known as Airborne Release Fractions. An Airborne Release Fraction (ARF) is that fraction of the Material At Risk (MAR) that may be suspended and transported from the point of release to potential recipients (i.e., public, workers, or environment). The ARF is dependent upon both the physical and chemical form of the material. While ARFs are directly associated with the development of the Category 2 Threshold Quantities, it is not so apparent with the case of Category 3 Threshold Quantities. The Hazard Category 3 Threshold Quantity listed in the DOE-STD-1027-92 document defines the minimum quantity of a radionuclide that would cause a DOE facility to be classified as a nuclear facility. The Hazard Category 3 Threshold Quantities are determined by multiplying by 20 the Environmental Protection Agency (EPA) threshold quantities from 40 CFR 302.4, Designation of Hazardous Substances. These EPA threshold quantities are based on release fractions and so it is appropriate to compare conservatively assumed default values versus values specifically applicable to the physical and chemical form of the material at risk and the energetics of the mechanism for release.

The ARFs that are provided in DOE-STD-1027-92 are meaningful to material forms commonly encountered in DOE fuel fabrication, reprocessing facilities, and nuclear reactors. In many cases, these ARFs represent radionuclides that are in a more dispersible form and/or with larger sources of energy (pressure gradient, temperature gradient, electrical potential) available for triggering dispersion than those that may be routinely encountered in target irradiations for medical radioisotope production operations. The solid irradiated targets do not allow for the inadvertent release of radioactive material from inside as long as their integrity is not compromised. If and when the integrity is found to be compromised (very rarely) as a result of the exposure to the beam current combined with an undetected flaw in the sealing of the target, leakage of the radioactive contents is detected as a build-up of activity in the target cooling water which is monitored and filtered / processed to remove and trap radioactivity, thereby preventing the dispersive release of the irradiated target contents.. Therefore, these ARFs may not provide a representative hazard categorization for such facilities. (See Table A - DOE-STD-1027-92 Airborne Release Fractions, below, for conservative values subject to review.)

This methodology is similar to that used at Hanford [Project Hanford Procedures - Hazard and Accident Analysis Procedure, HNF-PRO-704] and already approved by DOE for the Uranium Trioxide (UO_3) Building Hazards Classification - Deactivated State, (WHC-SD-CP-HC-004, Rev.0).

TABLE A - DOE-STD-1027-92 Airborne Release Fractions Table

MATERIAL FORMS	RADIONUCLIDES	ARF
GASES	Tritium, Krypton, Xenon, Argon, Radon	1.0
HIGHLY VOLATILE	Phosphorus, Sulfur, Potassium, Iodine, Pyrophoric Sodium, Bromine	0.5
SEMI-VOLATILE	Selenium, Mercury, Cesium, Polonium, Tellurium, Ruthenium, Carbon	1E-03
SOLIDS/POWDERS/LIQUIDS	All Materials Not Listed Above	1E-03

In many cases, these ARFs represent radionuclides that are in a more dispersible form than those to be encountered in the Brookhaven LINAC Isotope Producer in the handling of the Xe-127 production targets (and other routine isotope production targets). Therefore, the above ARFs may not provide a representative hazard categorization for the Brookhaven LINAC Isotope Producer (and similarly, for other EM facilities). To compensate for this effect, EM developed an alternate set of ARFs that are based on the research that is compiled within DOE-HDBK-3010.

These ARFs are presented below in Table B - Airborne Release Fractions for BLIP Categorization (**ARF_{HC}**).

Once the appropriate **ARF_{HC}** is determined, this value is to be ratioed to the applicable DOE-STD-1027-92 ARF because these ARFs are used to determine the threshold quantities. This ratio will be referred to as **R_{HC}** and can be expressed mathematically as **ARF_{HC} / ARF**. [The determination of **R_{HC}** is necessary because the threshold quantities, which are generally based on the DOE-STD-1027-92 ARFs (or 40CFR302.4 ARFs), need to be adjusted to reflect the use of the ARF_{HC}]. Use of the **R_{HC}** will allow rote application of the threshold quantities.

TABLE B - Airborne Release Fractions for BLIP Categorization (ARF_{HC})

MATERIAL FORM	ARF_{HC}
Contaminated combustible materials in closed metal containers, drums, hot cells, or metal transfer pigs.	
A. In generic metal containers or drums or metal transfer pigs[a]	5E-04
B. In WIPP Certified metal containers or drums or hot cells (or fitted w/filter) [b]	1E-04
C. Non-metal containers	1E-03
Contaminated non-combustible solids/powders/liquids in closed metal containers, drums, hot cells, or metal transfer pigs [a]	5E-05
Fixed matrix forms in closed metal containers, drums, hot cells, or metal transfer pigs (concrete, vitrified materials) [c]	1E-06
Widely dispersed low level contamination attached to inert material (i.e., contaminated soil, surface contamination, etc.) [d]	5E-06

(a) A mixture of metal containers, drums, hot cells, or metal transfer pigs with some fraction assumed to be fitted with filters to avoid over-pressurization. This fraction could be less than half.

(b) It is assumed that all metal containers, drums or hot cells are fitted with filters to avoid pressurization or are WIPP certified.

(c) This material form is to include most remediation activities and some decontamination activities after loose, readily removable contamination has been removed from the facility or segment.

(d) This material is to include most remediation activities and some decontamination activities after loose, readily removable contamination has been removed from the facility or segment.

The inventories expected to be found within the BLIP are as displayed on the following four tables. The tables include;

Table 1 - BLIP Irradiated Targets & Cooling Water - Proposed Inventory for Categorization Basis
Table 2 - BLIP CsCl + 200 MeV Protons to Produce Xe-127
Table 3 - BLIP Steel Targets
Table 4 - BLIP Niobium Targets

Each table reflects the modified Hazard Category 3 Thresholds for only some elements (all isotopes thereof), based upon the respective ratios of the DOE-STD-1027-92 ARFs and the DOE Hazard Categorization for BLIP Facility ARFs. These ARFs are dependent upon the form of the material (which defines its dispersibility) and the available energy for causing such a dispersion. The ARFs used were the applicable ones from the respective tables already included. The gaps in the column of ARF ratio, reflect the continued use of the extremely conservative value of release fraction as originally given in DOE-STD-1027-92.

For example, on Table A - DOE-STD-1027-92 Airborne Release Fraction Table, the element Iodine is included in the group of radionuclides identified as "Highly Volatile", with an Airborne release fraction given as 0.5. The BLIP irradiated targets contain radioiodine in solid crystalline form (not highly volatile). This is reflected on Table B - Airborne Release Fractions for BLIP Categorization (ARF_{HC}), as "Contaminated non-combustible solids/powders/liquids in closed metal containers, drums, hot cells, or metal transfer pigs" with an airborne release fraction of 5E-05. The ratio of 5E-05 to 0.5 is 1E-04 or 0.0001, the value listed in the A.R.F. Ratio column for all isotopes of Iodine in Table 2 - BLIP CsCl + 200 MeV Protons to Produce Xe-127. This value (0.0001) is then used to offset the radio-iodine threshold values to compensate for the much lower ARF_{HC}. Divide the original Category 3 threshold value by the ratio of the respective ARFs to get the new value. Original Category 3 threshold for I-126 = 4.6E-01 Ci. Modified value as seen on Table 2, BLIP CsCl + 200 MeV Protons to Produce Xe-127, is 4.6E-01/0.0001 = 4.6E+03 Ci.

The results clearly show that the inventories analyzed (current and future) do not approach a significant fraction of the Nuclear Hazard Category 3 Inventory Threshold Values, once adjustments are made for some of the extremely conservative isotopes by use of Airborne Release Fraction ratios, in accordance with the guidance provided by DOE-STD-1027-92 and DOE-HDBK-3010-94. Therefore, the BLIP facility should remain as currently categorized, i.e., a Radiological Facility.

Conclusion

Doubling the ESR dose calculation results in Appendix B would give the expected dose to the public in the event of a release of all 4 Ci of Xe-127 (<2E-04 mrem). Using the approach put forward here (previously approved by DOE for use at Hanford), yields a total inventory of less than 10% of the Category 3 threshold [consisting of the sum of Table 1 @ 1.27%, Table 2 @ 4.07%, Table 3 @ 2.14%, and Table 4 @ 0.37% (= 7.85%)].

Table 1 - BLIP Irradiated Targets & Cooling Water - Proposed Inventory for Categorization Basis

RADIO-NUCLIDE	HALFLIFE [Yrs]	SPEC. ACT. [Ci/gm]	INVENTORY [Ci]	CAT.3 LIMIT [Ci]	FRACTION OF LIMIT	FRACTION OF TOTAL	MAT'L FORM	A.R.F. RATIO
003H	1.23E+01	9.71E+03	5.00E-02	1.60E+04	3.13E-06	0.02%		
007Be	1.46E-01	3.50E+05	2.40E+00	1.48E+04	1.62E-04	1.28%		
010Be	1.60E+06	2.24E-02	1.60E-10	1.04E+02	1.54E-12	0.00%		
010C	6.11E-07		1.00E-06	N/A	N/A	N/A		
011C	3.89E-05	8.39E+08	4.00E+00	3.60E+04	1.11E-04	0.88%		
013N	1.90E-05		1.47E+00	N/A	N/A	N/A		
014C	5.73E+03	4.46E+00	1.33E-06	4.20E+02	3.17E-09	0.00%		
014O	2.24E-06		3.10E-02	N/A	N/A	N/A		
015O	3.87E-06		4.00E+00	N/A	N/A	N/A		
018F	2.09E-04	9.52E+07	1.67E-02	7.20E+05	2.32E-08	0.00%		
022Na	2.60E+00	6.24E+03	2.72E-04	2.40E+02	1.13E-06	0.01%		
024Na	1.71E-03	8.70E+06	7.70E-02	3.00E+02	2.57E-04	2.03%		
026Al	7.20E+05	1.92E-02	8.34E-09	2.40E+02	3.48E-11	0.00%		
028Mg	2.39E-03	5.35E+06	4.00E-03	7.40E+02	5.41E-06	0.04%		
031Si	2.99E-04	3.86E+07	5.14E-01	3.20E+05	1.61E-06	0.01%		
032Si	3.30E+02	2.48E+01	9.48E-07	5.20E+01	1.82E-08	0.00%		
032P	3.91E-02	2.86E+05	4.35E+00	1.20E+05	3.62E-05	0.29%	SOLID	0.0001
033P	1.56E+05	1.56E+05	7.09E-01	9.40E+05	7.54E-07	0.01%	SOLID	0.0001
035S	2.39E-01	4.27E+04	1.82E-01	7.80E+05	2.33E-07	0.00%	SOLID	0.0001
036Cl	3.01E+05	3.30E-02	7.08E-07	3.40E+02	2.08E-09	0.00%		
037Ar	9.59E-02		6.26E-01	N/A	N/A	N/A		
041Ar	2.08E-04	4.18E+07	5.00E-03	6.00E+02	8.33E-06	0.07%		
041Ca	1.03E+05	6.23E-02	4.68E-09	1.60E+03	2.93E-12	0.00%		
045Ca	4.52E-01	1.78E+04	4.00E-05	1.10E+03	3.64E-08	0.00%		
046Sc	2.30E-01	3.38E+04	3.90E-04	3.60E+02	1.08E-06	0.01%		
047Sc	9.37E-03	8.29E+05	1.20E-03	5.80E+03	2.07E-07	0.00%		
048V	4.37E-02	1.68E+05	7.50E-03	6.40E+02	1.17E-05	0.09%		
049V	9.03E-01	8.08E+03	8.90E-04	4.40E+04	2.02E-08	0.00%		
051Cr	7.58E-02	9.24E+04	3.00E-02	2.20E+04	1.36E-06	0.01%		
052Mn	1.53E-02	4.49E+05	1.01E-01	3.40E+02	2.97E-04	2.35%		
053Mn	3.70E+06	1.82E-03	3.90E-09	3.00E+04	1.30E-13	0.00%		
054Mn	8.56E-01	7.74E+03	1.70E-02	8.80E+02	1.93E-05	0.15%		
055Fe	2.70E+00	2.41E+03	8.04E-03	5.40E+03	1.49E-06	0.01%		
056Co	2.16E-01	2.96E+04	5.90E-02	2.20E+02	2.68E-04	2.12%		
056Mn	2.94E-04	2.17E+07	9.40E-02	2.80E+03	3.36E-05	0.27%		
056Ni	1.67E-02	3.82E+05	7.50E-03	4.60E+02	1.63E-05	0.13%		
057Co	7.42E-01	8.46E+03	5.20E-02	6.00E+03	8.67E-06	0.07%		
057Ni	4.12E-03	1.52E+06	1.59E-01	6.00E+02	2.65E-04	2.09%		
058Co	1.94E-01	3.18E+04	2.26E-01	9.00E+02	2.51E-04	1.98%		
059Fe	1.22E-01	4.97E+04	5.20E-03	6.00E+02	8.67E-06	0.07%		
059Ni	7.50E+04	8.08E-02	8.70E-07	1.18E+04	7.37E-11	0.00%		
060Co	5.27E+00	1.13E+03	1.75E-03	2.80E+02	6.25E-06	0.05%		
061Co	1.88E-04	3.11E+07	2.82E-01	8.00E+04	3.53E-06	0.03%		
061Cu	3.89E-04	1.51E+07	7.95E+00	1.64E+04	4.85E-04	3.83%		
062Zn	1.06E-03	5.46E+06	2.47E+00	5.20E+03	4.75E-04	3.75%		
063Ni	1.00E+02	5.91E+01	1.15E-01	5.40E+03	2.13E-05	0.17%		
064Cu	1.45E-03	3.86E+06	4.01E+00	1.54E+05	2.60E-05	0.21%		
065Ni	2.87E-04	1.91E+07	1.15E-01	9.00E+03	1.28E-05	0.10%		
065Zn	6.68E-01	8.24E+03	3.18E-01	2.40E+02	1.33E-03	10.47%		
066Ga	1.07E-03	5.05E+06	7.60E-01	1.10E+03	6.91E-04	5.46%		
067Cu	7.06E-03	7.56E+05	7.50E-01	7.20E+03	1.04E-04	0.82%		
067Ga	8.93E-03	5.98E+05	4.28E+00	4.80E+03	8.92E-04	7.04%		
068Ga	1.29E-04	4.07E+07	1.17E+01	3.20E+05	3.67E-05	0.29%		
068Ge	7.89E-01	6.67E+03	1.50E+00	1.00E+03	1.50E-03	11.84%		
071Ge	3.23E-02	1.56E+05	1.78E+00	4.20E+05	4.24E-06	0.03%		
073Se	8.16E-04	6.01E+06	1.39E-02	1.90E+03	7.32E-06	0.06%		
073As	2.20E-01	2.23E+04	3.00E-03	5.40E+03	5.56E-07	0.00%		

Table 1 - Continued

RADIO-NUCLIDE	HALFLIFE [Yrs]	SPEC. ACT. [Ci/gm]	INVENTORY [Ci]	CAT.3 LIMIT [Ci]	FRACTION OF LIMIT	FRACTION OF TOTAL	MAT'L FORM	A.R.F. RATIO
074As	4.87E-02	9.94E+04	1.23E-02	1.02E+03	1.21E-05	0.10%		
075Se	3.28E-01	1.45E+04	2.10E-03	3.20E+02	6.56E-06	0.05%		
076As	3.00E-03	1.57E+06	4.60E-03	2.60E+03	1.77E-06	0.01%		
077As	4.43E-03	1.05E+06	9.20E-03	2.20E+04	4.18E-07	0.00%		
077Br	6.51E-03	7.27E+05	2.80E-01	3.00E+03	9.33E-05	0.74%		
079Se	6.50E+04	6.97E-02	1.13E-08	3.60E+02	3.14E-11	0.00%		
079Kr	4.00E-03	1.13E+06	1.37E+00	4.00E+03	3.43E-04	2.70%		
080Brm	3.31E-05	8.87E+06	1.90E-01	1.04E+05	1.83E-06	0.01%		
081Kr	2.10E+05	2.10E-02	5.20E-07	1.40E+05	3.71E-12	0.00%		
081Rb	5.22E-04	8.45E+06	6.16E+00	5.80E+03	1.06E-03	8.39%		
082Br	4.03E-03	1.08E+06	9.70E-02	3.40E+02	2.85E-04	2.25%		
082Sr	6.84E-02		2.40E+00	N/A	N/A	N/A		
083Br	2.73E-04	1.58E+07	9.20E-02	6.20E+05	1.48E-07	0.00%		
083Rb	2.36E-01	1.83E+04	2.09E+00	8.00E+03	2.61E-04	2.06%	SOLID	0.05
083Krm	2.09E-04	2.06E+07	1.32E+00	2.00E+06	6.60E-07	0.01%		
084Rb	9.01E-02	4.74E+04	1.76E+00	8.00E+03	2.20E-04	1.74%	SOLID	0.05
085Sr	1.78E-01	2.37E+04	1.03E+00	1.44E+03	7.15E-04	5.65%		
085Kr	1.07E+01	3.93E+02	1.65E-03	2.00E+04	8.25E-08	0.00%		
085Krm	5.11E-04	8.23E+06	3.37E-01	4.00E+03	8.43E-05	0.67%		
086Rb	5.11E-02	8.14E+04	1.65E+00	1.00E+04	1.65E-04	1.30%	SOLID	0.05
086Y	1.68E-03	2.47E+06	9.00E-03	4.60E+02	1.96E-05	0.15%		
086Zr	1.88E-03	2.21E+06	1.06E-02	4.40E+03	2.41E-06	0.02%		
087Rb	4.73E+10	8.75E-08	4.86E-06	6.00E+02	8.10E-09	0.00%		
087Srm	3.20E-04	1.28E+07	7.78E-01	1.36E+04	5.72E-05	0.45%		
087Y	9.16E-03	4.49E+05	1.00E-02	1.00E+03	1.00E-05	0.08%		
088Y	2.92E-01	1.39E+04	2.98E-04	2.80E+02	1.06E-06	0.01%		
088Zr	2.28E-01	1.78E+04	3.00E-03	1.92E+03	1.56E-06	0.01%		
089Zr	8.95E-03	4.49E+05	5.44E-02	3.20E+03	1.70E-05	0.13%		
090Y	7.00E-03	5.44E+05	3.00E-03	1.42E+03	2.11E-06	0.02%		
090Nb	1.67E-03	2.39E+06	1.25E-01	3.00E+02	4.17E-04	3.29%		
091Y	1.60E-01	2.45E+04	3.86E-05	3.60E+02	1.07E-07	0.00%		
093Mo	3.50E+03	1.10E+00	1.16E-06	2.00E+03	5.82E-10	0.00%		
093Nbm	2.80E+01	2.83E+02	4.64E-05	2.00E+03	2.32E-08	0.00%		
093Zr	1.53E+06	2.51E-03	2.20E-11	6.20E+01	3.55E-13	0.00%		
094Nb	2.03E+04	1.87E-01	1.12E-08	2.00E+02	5.60E-11	0.00%		
095Nb	9.60E-02	3.91E+04	8.19E-04	9.60E+02	8.53E-07	0.01%		
095Tcm	2.28E-03		3.80E-02	N/A	N/A	N/A		
096Nb	2.66E-03	1.40E+06	3.00E-03	4.40E+02	6.82E-06	0.05%		
096Tc	1.17E-02	3.18E+05	3.00E-01	3.20E+02	9.38E-04	7.40%		
097Nb	1.37E-04	2.69E+07	4.00E-04	1.48E+04	2.70E-08	0.00%		
097Ru	7.94E-03	4.64E+05	1.30E+00	2.40E+03	5.40E-04	4.27%		
097Tc	2.60E+06	1.42E-03	1.70E-09	1.78E+04	9.55E-14	0.00%		
097Tcm	2.44E-01	1.55E+04	1.82E-02	2.60E+03	6.99E-06	0.06%		
099Tc	2.13E+05	1.70E-02	1.50E-09	1.70E+03	8.82E-13	0.00%		
099Mo	7.53E-03	4.78E+05	3.00E-03	3.40E+03	8.82E-07	0.01%		
099Tcm	6.87E-04	5.26E+06	2.16E-01	1.70E+04	1.27E-05	0.10%		
103Ru	1.08E-01	3.23E+04	8.00E-03	1.56E+03	5.13E-06	0.04%		
103Pd	4.64E-02	7.48E+04	7.11E-02	6.20E+03	1.15E-05	0.09%		
SUMMATION OF FRACTIONS				**Cat. 3 @**	**1.27%**			

Table 2 - BLIP CsCl + 200 MeV Protons to Produce Xe-127

RADIO-NUCLIDE	HALFLIFE [Yrs]	SPEC. ACT. [Ci/gm]	INVENTORY [Ci]	CAT.3 LIMIT [Ci]	FRACTION OF LIMIT	FRACTION OF TOTAL	MAT'L FORM	A.R.F. RATI[illegible]
007Be	1.46E-01	3.50E+05	2.40E+00	1.48E+04	1.62E-04	0.40%		
010Be	1.60E+06	2.24E-02	1.60E-10	1.04E+02	1.54E-12	0.00%		
014C	5.73E+03	4.46E+00	1.33E-06	4.20E+02	3.17E-09	0.00%		
018F	2.09E-04	9.52E+07	1.25E+01	7.20E+05	1.73E-05	0.04%		
113Sn	3.15E-01	1.00E+04	1.26E-02	1.30E+03	9.69E-06	0.02%		
113Inm	1.89E-04	1.67E+07	1.39E-02	3.00E+04	4.63E-07	0.00%		
114Inm	2.28E-06	2.31E+04	8.00E-03	2.20E+02	3.64E-05	0.09%		
115Inm	4.97E-04	6.08E+06	1.00E-02	1.78E+04	5.62E-07	0.00%		
116Te	2.84E-04	1.09E+07	3.96E-01	8.00E+04	4.95E-06	0.01%		
117Sb	3.19E-04	9.57E+06	3.65E-01	3.00E+04	1.22E-05	0.03%		
117Snm	3.72E-02	8.20E+04	3.00E-02	2.20E+03	1.36E-05	0.03%		
117Te	1.17E-04		7.89E-01	N/A	N/A	N/A		
118Sbm	5.95E-06	5.31E+06	1.39E-02	9.80E+02	1.42E-05	0.03%		
118Te	1.64E-02		2.22E+00	N/A	N/A	N/A		
119Sb	4.35E-03	6.91E+05	2.15E-01	5.80E+04	3.71E-06	0.01%		
119Te	1.28E-02		1.41E+00	N/A	N/A	N/A		
119Tem	1.83E-03		1.41E+00	N/A	N/A	N/A		
121Te	4.22E-01	6.35E+04	9.46E-01	1.34E+03	7.06E-04	1.74%		
121Tem	4.60E-02	7.01E+03	2.60E-01	3.20E+02	8.13E-04	2.00%		
122Sb	7.39E-03	3.96E+05	2.09E-02	1.86E+03	1.12E-05	0.03%		
123I	1.50E-03	1.93E+06	5.70E+00	9.00E+06	6.34E-07	0.00%	SOLID	0.0001
123Tem	3.28E-01	8.91E+03	1.80E-01	4.00E+02	4.51E-04	1.11%		
123Xe	2.44E-04	1.23E+07	5.63E+00	1.20E+03	4.69E-03	11.54%		
124I	1.13E-02	2.52E+05	4.25E+00	2.40E+04	1.77E-04	0.44%	SOLID	0.00[illegible]
124Sb	1.65E-01	1.75E+04	6.00E-03	3.60E+02	1.67E-05	0.04%		
125I	1.65E-01	1.74E+04	2.34E+00	5.60E+03	4.18E-04	1.03%	SOLID	0.0001
125Tem	1.59E-01	1.80E+04	9.88E-02	7.20E+02	1.37E-04	0.34%		
125Xe	1.85E-03	1.47E+06	4.66E+00	4.00E+03	1.16E-03	2.86%		
126Ba	1.88E-04	1.55E+07	7.82E-01	2.00E+04	3.91E-05	0.10%		
126I	3.54E-02	7.96E+04	2.51E+00	4.60E+03	5.45E-04	1.34%	SOLID	0.0001
127Cs	7.07E-04	3.95E+06	1.19E+01	6.60E+03	1.80E-03	4.43%		
127Te	2.98E-01	2.64E+06	9.00E-03	1.44E+05	6.25E-08	0.00%		
127Tem	1.07E-03	9.43E+03	3.00E-03	4.00E+02	7.50E-06	0.02%		
127Xe	9.97E-02	2.82E+04	4.00E+00	2.00E+03	2.00E-03	4.92%		
128Ba	6.65E-03	4.20E+05	7.02E+00	1.90E+03	3.70E-03	9.09%		
129Ba	2.51E-04		5.58E+00	N/A	N/A	N/A		
129Cs	3.66E-03	7.58E+05	1.43E+01	3.80E+03	3.75E-03	9.23%		
129I	1.57E+07	1.76E-04	8.30E-09	6.00E-02	1.38E-07	0.00%		
129Xem	2.43E-02	1.27E+05	5.03E+00	4.00E+04	1.26E-04	0.31%		
130I	1.41E-03	1.95E+06	4.69E-01	1.26E+06	3.72E-07	0.00%	SOLID	0.0001
131Ba	3.23E-02	8.45E+04	5.73E+00	1.86E+03	3.08E-03	7.58%		
131Cs	2.65E-02	1.03E+05	1.57E+01	2.80E+04	5.61E-04	1.38%		
131I	2.20E-02	1.24E+05	3.65E-01	9.20E+03	3.97E-05	0.10%	SOLID	0.0001
131Xem	3.24E-02	8.38E+04	3.13E+00	8.00E+04	3.91E-05	0.10%		
132Cs	1.77E-02	1.53E+05	1.83E+01	1.14E+03	1.61E-02	39.57%		
133Ba	1.05E+01	2.50E+02	1.62E-02	1.10E+03	1.47E-05	0.04%		
133Bam	4.44E-03	6.06E+05	1.62E-02	1.08E+04	1.50E-06	0.00%		
SUMMATION OF FRACTIONS				**Cat. 3 @**	**4.07%**			

Table 3 - BLIP Steel Targets

RADIO-NUCLIDE	HALFLIFE [Yrs]	SPEC. ACT. [Ci/gm]	INVENTORY [Ci]	CAT.3 LIMIT [Ci]	FRACTION OF LIMIT	FRACTION OF TOTAL	MAT'L FORM	A.R.F. RATIO
043Sc	4.45E-04	1.87E+07	2.00E+00	3.80E+04	5.26E-05	0.25%		
044Sc	6.69E-03	1.81E+07	2.00E+00	2.60E+03	7.69E-04	3.59%		
044Scm	4.48E-04	1.22E+06	2.00E+00	1.90E+03	1.05E-03	4.91%		
046Sc	2.30E-01	3.39E+04	2.00E+00	7.20E+03	2.78E-04	1.30%	SOLID	0.05
047Ca	1.24E-02	6.13E+05	2.00E+00	1.40E+04	1.43E-04	0.67%	SOLID	0.05
047Sc	9.37E-03	8.29E+05	2.00E+00	5.80E+03	3.45E-04	1.61%		
048Cr	2.46E-03	2.84E+06	5.00E+01	5.20E+04	9.62E-04	4.49%	SOLID	0.05
048Sc	4.98E-03	1.49E+06	4.60E+00	5.20E+03	8.85E-04	4.13%	SOLID	0.05
048V	4.37E-02	1.68E+05	1.40E+01	1.28E+04	1.09E-03	5.11%	SOLID	0.05
049Cr	8.00E-05	9.12E+07	5.00E+01	1.96E+05	2.55E-04	1.19%		
049V	9.03E-01	8.08E+03	1.40E+01	4.40E+04	3.18E-04	1.49%		
051Cr	7.58E-02	9.24E+04	5.00E+01	4.40E+05	1.14E-04	0.53%	SOLID	0.05
051Mn	8.78E-05	7.98E+07	2.40E+00	5.20E+05	4.62E-06	0.02%		
052Fe	9.44E-04	7.28E+06	1.00E-01	1.00E+04	1.00E-05	0.05%		
052Mn	1.53E-02	4.49E+05	2.40E+00	6.80E+03	3.53E-04	1.65%	SOLID	0.05
052Mnm	4.07E-05	1.71E+08	2.40E+00	2.40E+04	1.00E-04	0.47%		
053Mn	3.70E+06	1.82E-03	2.40E+00	3.00E+04	8.00E-05	0.37%		
054Mn	8.56E-01	7.74E+03	5.50E+01	1.76E+04	3.13E-03	14.59%	SOLID	0.05
055Co	2.00E-03	3.25E+06	2.50E+01	1.96E+04	1.28E-03	5.95%	SOLID	0.05
055Fe	2.70E+00	2.41E+03	1.00E-01	5.40E+03	1.85E-05	0.09%		
056Co	2.16E-01	2.96E+04	2.40E+01	4.40E+03	5.45E-03	25.46%	SOLID	0.05
056Mn	2.94E-04	2.17E+07	5.50E+01	5.60E+04	9.82E-04	4.58%	SOLID	0.05
056Ni	1.67E-02	3.82E+05	3.20E+00	9.20E+03	3.48E-04	1.62%	SOLID	0.05
057Co	7.42E-01	8.46E+03	1.40E+01	1.20E+05	1.17E-04	0.54%	SOLID	0.05
057Ni	4.12E-03	1.52E+06	2.00E+01	1.20E+04	1.67E-03	7.78%	SOLID	0.05
058Co	1.94E-01	3.18E+04	1.40E+01	1.80E+04	7.78E-04	3.63%	SOLID	0.05
058Com	1.04E-03	5.91E+06	1.40E+01	6.20E+06	2.26E-06	0.01%		
059Fe	1.22E-01	4.97E+04	1.00E-02	6.00E+02	1.67E-05	0.08%		
059Ni	7.50E+04	8.08E-02	1.00E+00	1.18E+04	8.47E-05	0.40%		
060Co	5.27E+00	1.13E+03	1.00E+00	5.60E+03	1.79E-04	0.83%	SOLID	0.05
060Fe	1.50E+06	5.96E-02	1.00E-02	1.78E+01	5.62E-04	2.62%		
SUMMATION OF FRACTIONS				**Cat. 3 @**	**2.14%**			

Table 4 - BLIP Niobium Targets

RADIO-NUCLIDE	HALFLIFE [Yrs]	SPEC. ACT. [Ci/gm]	INVENTORY [Ci]	CAT.3 LIMIT [Ci]	FRACTION OF LIMIT	FRACTION OF TOTAL	MAT'L FORM	A.R.F. RATIO
088Zr	2.28E-01	1.78E+04	3.20E-01	1.92E+03	1.67E-04	4.52%		
089Zr	8.95E-03	4.49E+05	2.30E+00	6.40E+04	3.59E-05	0.97%	SOLID	0.05
090Mo	6.50E-04	6.14E+06	7.80E+00	5.60E+04	1.39E-04	3.78%	SOLID	0.05
090Nb	1.67E-03	2.39E+06	5.00E+00	6.00E+03	8.33E-04	22.59%	SOLID	0.05
091Nb	7.00E+02		4.00E-03	N/A	N/A	N/A		
092Nbm	2.77E-02		7.70E+00	N/A	N/A	N/A		
093Mo	3.50E+03	1.10E+00	2.50E-03	2.00E+03	1.25E-06	0.03%		
093Mom	7.87E-04	4.92E+06	4.22E+01	1.68E+04	2.51E-03	68.10%	SOLID	0.05
SUMMATION OF FRACTIONS				Cat. 3 @	0.37%			

V. COMMITMENTS

The commitments which are necessary to maintain to ensure the validity of the Facility Hazard Categorization Review include:

(i) those commitments made within and as part of the approved Safety Assessment Document for the Brookhaven LINAC Isotope Producer dated March 1996;

(ii) those commitments made within and as part of the approved Brookhaven LINAC Isotope Producer (BLIP) Facility Manual dated March 3, 1996;

(iii) those commitments made in resolution of the comments received as part of Experimental Safety Review 97-03, which will all be resolved or addressed before regular production runs of Xe-127 are begun; and

(iv) a graduated series of test runs for the production of Xe-127 to re-confirm the accuracy of the theoretical calculation of isotopes produced as a function of target irradiation, prior to full production runs (4 Ci of Xe-127 produced), with the oversight, input and concurrence of the DOE Facility Representative(s) on the methodology and follow-through.

VI. REFERENCES

1) DOE Order 5480.23, Nuclear Safety Analysis Reports, Change 1 dated 3/10/94.

2) DOE Order 5480.25, Safety of Accelerator Facilities, dated November 3, 1992.

3) DOE Order 5480.25 Guidance, Guidance for an Accelerator Facility Safety Program, dated September 1, 1993.

4) BNL Implementation Plan for Brookhaven LINAC Isotope Producer under DOE Accelerator Safety Order 5480.25, dated April 25, 1994.

5) DOE-STD-1027-92, Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports, dated December 1992, including Change Notice No. 1 dated September 1997.

6) DOE-EM-STD-5502-94, Hazard Baseline Documentation, dated August 1994.

7) DOE-HDBK-3010-94, Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities, Volume I - Analysis of Data & Volume II - Appendices, dated December 1994.

8) DOE-TIC-11026, Radioactive Decay Data Tables - A Handbook of Decay Data for Application to Radiation Dosimetry and Radiological Assessment, D.C. Kocher, 1984

9) Los Alamos National Laboratory Fact Sheet LA-12981-MS, Table of DOE-STD-1027-92 Hazard Category 3 Threshold Quantities for the ICRP-30 List of 757 Radionuclides, issued August 1995.

10) Project Hanford Procedure HNF-PRO-704, Hazard and Accident Analysis Process, Rev. 0 dated 12/29/97.

11) BNL Safety Assessment Document for Brookhaven LINAC Isotope Producer, by Dr. M. Plotkin and Dr. L. F. Mausner, dated March 1996.

12) BNL Memorandum from K. Kolsky to L. Mausner dated February 23, 1998, on Xe-127 Isotope Inventories.

13) BNL Memorandum from K. Kolsky to S. Moss dated May 13, 1998, on BLIP and TPL Isptope Inventory.

14) IAEA-SM-171/38, The Brookhaven LINAC Isotope Producer (BLIP), Richards et al., 1973.

15) The Design and Operation of the Upgraded BLIP Facility for Radionuclide Research and Production, Mausner et al., Appl. Radiat. Isot. Vol.41, No. 4 , 1990.

16) The Upgrade of the Brookhaven LINAC Isotope Producer (BLIP) and the BNL LINAC, Mausner and Alessi, 1997.

APPENDIX A

DOE Program Office Letter of Request

Department of Energy
Germantown, MD 20874-1290

June 19, 1998

Mr. Peter Kelley
U.S. Department of Energy
Brookhaven Area Office
53 Bell Avenue
Building 464
Upton, New York 11973

Dear Mr. Kelley:

The Isotope Production and Distribution Program has the responsibility to provide radioisotopes of interest to the medical research community. This responsibility includes providing isotopes that are not currently available from other sources, but that can be produced in the Department of Energy's accelerators and reactors. One such isotope is xenon-127. We have requested that the Medical Department of the Brookhaven National Laboratory reestablish its capability to produce xenon-127. This isotope, which Brookhaven had produced until the early 1990s, is to be used by nuclear medicine investigators to improve their ability to perform brain scans. The Isotope Program has received six requests for xenon-127 from five medical schools and research organizations.

Over the past several years, because of budget restrictions and the problems that have arisen in the operation of some of our facilities, the Department's reputation as a reliable supplier of radionuclides has been severely damaged. We believe that our ability to provide xenon-127 is critical to once again establishing the Department as a reliable supplier. In addition, the use of xenon-127 has the potential to improve medical diagnoses. Therefore, we would appreciate any assistance that you can provide in facilitating the Brookhaven National Laboratory in its program to produce xenon-127.

Sincerely,

Norton Haberman

Norton Haberman, Ph.D.
Senior Technical Advisor
Isotope Production and Distribution
Program
Office of Nuclear Energy,
Science and Techology

APPENDIX B

Experimental Safety Review ESR 97-03

BROOKHAVEN NATIONAL LABORATORY
MEDICAL DEPARTMENT

MEMORANDUM

DATE: February 25, 1998

TO: L. Mausner

FROM: K. Conkling

SUBJECT: **Experiment Safety Review ESR 97-03**

The Medical Department Experiment Safety Review Committee met today to review the documentation you submitted for the subject ESR. The Committee found the following:

Overview
This is a proposal to begin work on the development of a Xe-127 production process. The same research group performed similar work from 1973-1992. Production would resume using essentially the same technology as was successful in the past with these exceptions:

a) The targets will be punctured with a newly designed pneumatic tool.

b) Recovery of Xe-127 from the irradiated targets would no longer utilize high heat to melt the target material. Instead a safer methodology using water to recover the Xe has been developed.

All other steps will be SOP.

Comments
1. A noble gas attachment must be installed on an air monitor in the Target Processing Lab. It is recommended that the PI contact the HP Group, S&EP to determine whether a similar attachment should be attached at the BLIP.
2. It is recommended that the PI obtain a document from G. Schroeder, Environmental Group. S&EP, stating that a catastrophic loss of Xe and other species up the stack at the BLIP would not violate site boundary permit limits.
3. The new puncturing mechanism must be tested on a 'cold' target prior to use in the work.
4. The PI must contact G. Meinken (ESR Committee member) to inspect the collection and dispensing systems after they are assembled and are being tested.
5. The ESR must be reformatted using the revised form.
6. The PI should note the routine effluent monitoring that is performed at both the BLIP and the TPL stacks (item 11 on form).
7. The rad material inventory during such runs will put both the BLIP and the TPL in a Non-Reactor Nuclear Facility Category 3. The PI must pursue issue with cognizant S&EP staff. A BIO will have to be prepared before beginning a run, unless an exemption can be obtained.

cc: J. Bullis
J. Coderre
R. Colichio
G. Mienken
M. Miura
P. Sullivan

BROOKHAVEN NATIONAL LABORATORY

MEMORANDUM

DATE: May 12, 1998

TO: L. Mausner

FROM: G. Schroeder

SUBJECT: Xe-127 Release Analysis

Attached, you will find an evaluation of the public radiological dose consequences resulting from the accidental release of 2 Ci of xenon-127. The conclusions of the evaluation indicate that the resulting dose from such a release, even under the most conservative assumptions, would fall far below current standards and limits. If you have questions regarding this analysis, please contact me at extension 7045.

GS:rt
Attachment

cc: L. DeBobes
K. Conkling
R. Lee

EC5220.98

Dose Evaluation of Accidental Release of 2 Ci of ^{127}Xe

This review has been prepared by the Environmental Compliance Office to satisfy the requirements of the Medical Department Experimental Safety Review.

Process Description

Xenon-127, a beta/gamma-emitting noble gas isotope with a half life of 37 days, will be produced by the BLIP facility for use in lung ventilation imaging and brain blood flow studies. The manufacturing process involves the irradiation of a cesium fluoride target with 200 MeV protons at the BLIP facility, followed by separation of the ^{127}Xe from the target. The separation process will be carried out in hot cells at the Building 801 Target Processing Laboratory. The target will be placed into a holder where water is injected to dissolve the cesium fluoride. Helium is bubbled through the dissolved target, purging the ^{127}Xe from the water. The He/Xe combination is flowed through a gas train into a moisture trap, a hot silver trap to react with any radioiodines present, and finally through a liquid nitrogen-cooled coil. Xenon freezes in this coil while the helium is not trapped. Frozen ^{127}Xe is allowed to warm and is cryogenically transferred to a storage cylinder at LN_2 temperatures. The ^{127}Xe will be cryogenically transferred into flame-sealed glass ampoules for dispensation to off-site requestors.

Accidental Release Scenario

This evaluation examines the potential radiological impact of the accidental release of ^{127}Xe due to a leak in the gas containment system. If such a leak in the containment system were to develop, ^{127}Xe would escape into the air in the hot cell where it would be swept from the cell and into the building exhaust gas system. Once in this system, any gasses would pass through roughing filters, HEPA filters, and charcoal filters before exiting the HFBR's 98 meter stack. The only filter in this exhaust system which would provide any reduction in the atmospheric emission of ^{127}Xe is the charcoal filter. However, the collection efficiency of a charcoal filter for xenon is dependent on several factors and cannot be precisely known. For purposes of this evaluation, it is conservatively assumed that all 2 Ci of ^{127}Xe could be released. No credit is taken for potential partial capture of xenon by the charcoal filters.

Radiological Dose Evaluation

Normally, the EPA dose model CAP88-PC is used to estimate the potential effective dose equivalent to a member of the public from airborne radionuclides released from BNL. However, the accurate use of the model is restricted to annual, continuous releases; it is not to be used to evaluate the dosimetric consequences of an accidental, acute release. Therefore, this evaluation is based upon the atmospheric modeling equations of Sutton[1].

Since we are interested in evaluating the radiological dose to a member of the public, the distance from the release point to the receptor is chosen to be 2,000 meters; this is the approximate distance from the HFBR stack to the nearest site boundary, to the west. (Note that this distance is also accurate for evaluating the on-site apartment complex.) Charts of normalized dispersion functions have been developed by Hilsmeier[2] for stacks of varying heights. These charts plot uX/Q vs. various downwind distances and atmospheric stability classes. For a 100 meter stack and a receptor distance of 2,000 meters, the radionuclide concentration maxima is predicted to occur under Pasquill-Gifford Stability Class "C" (slightly unstable) conditions (see Figure 1). Higher concentrations are predicted closer to the release point, though these values are not relevant for estimating off-site doses.

For an elevated release point and a ground-level receptor along the centerline of the contaminant plume, the following equation allows computation of the air concentration.

$$X = \frac{Q}{\pi \sigma_y \sigma_z u}\left[\exp\left\{-\frac{h^2}{2\sigma_z^{\,2}}\right\}\right]$$

where

X = air concentration at receptor distance (Ci/sec)

Q = activity release rate (Ci/sec)

σ_y = horizontal dispersion parameter (m)

σ_z = vertical dispersion parameter (m)

u = mean wind speed (m/sec)

h = stack height (m)

For this evaluation, the following assumption are made:

1. The effective stack height is equal to the physical stack height, 98 m.
2. All 2 Ci of ^{127}Xe is released during the accident.
3. The duration of the release is one hour.
4. No ^{127}Xe is retained on the charcoal filters; any radioiodines present will be effectively retained by the charcoal filters.
5. Stability class conditions are "C", slightly unstable.
6. The mean wind speed, based on records for July, 1996 measurements at BNL's meteorological tower at the 88 meter height are 5.3 m/sec.
7. No significant decay of the ^{127}Xe occurs between the release point and the receptor.

Under these assumptions, the release rate Q is calculated:

$$Q = \frac{2\,Ci}{hr} \times \frac{hr}{60\,\min} \times \frac{\min}{60\,\sec} = 5.6E-4 \quad Ci/\sec$$

From Figures 2 and 3, the lateral and vertical dispersion coefficients, σ_y and σ_z, under stability class C conditions at a distance of 2,000 m are given as 200 and 120 m, respectively. Inserting these values into the air concentration equation gives

$$X = \frac{5.6E-4\ Ci\ \sec^{-1}}{\pi\ (200\ m)\ (120\ m)\ (5.3\ m\ \sec^{-1})}\left[\exp\left\{-\frac{(98\ m)^2}{2\ (120\ m)^2}\right\}\right] = \ 1.0E-9\ Ci\ m^{-3}$$

The external dose rate factor[3] for immersion in a semi-infinite, i.e., hemispherical, cloud of air containing ^{127}Xe is 1.33E+3 mrem/yr per uCi/m^3. If the amount of time spent immersed in such a semi-infinite, uniformly contaminated cloud is one hour, the effective dose equivalent, H_E, is calculated as

$$H_E = \frac{1.33E3\ mrem\ m^3}{yr\ \ uCi} \times \frac{10^6\ uCi}{Ci} \times \frac{1E-9\ Ci}{m^3} \times \frac{yr}{8.76E3\ hr} \times 1\ hr$$

$$H_E = \ 1.5E-4\ mrem$$

This conservatively assumes that the exposed individual resides outdoors for the duration of the exposure. The dose rate reduction factor recommended by DOE (see Ref. 3) for indoor residence is 0.5. This factor adjusts for photon shielding provided by the physical structure of a home or office. Applying this factor to the dose calculated above gives an effective dose equivalent of

$$H_E = \ 1.5E-4\ mrem \times 0.5 = 7.6E-5\ mrem$$

Conclusion

The DOE radiological dose limit for members of the public is 100 mrem/yr[4]. The EPA-specified dose limit for members of the public resulting from airborne radionuclides is 10 mrem/yr[5]. The typical dose received by a maximally exposed member of the public from routine BNL radiological airborne effluents is approximately 0.1 mrem/yr. Given this, no dose standards would be exceeded in the event of an accidental release of ^{127}Xe from the planned production run.

References

[1] Atomic Energy Commission. *Meteorology and Atomic Energy*, USAEC Report TID-24190; July, 1968.

[2] Hilsmeier, W.F. et al. *Graphs for Estimating Atmospheric Dispersion.* Oak Ridge National Laboratory Report ORO-545; July, 1962.

[3] *External Dose-Rate Conversion Factors for Calculation of Dose to the Public*, DOE/EH-0070, U.S. Deprartment of Energy, July, 1988.

[4] DOE Order 5400.5, *Radiation Protection of the Public and Environment*, U.S. Department of Energy, February, 1990.

[5] Title 40 CFR Part 61, Subpart H, *National Emissions Standards for Radionuclide Emissions from DOE Facilities*.

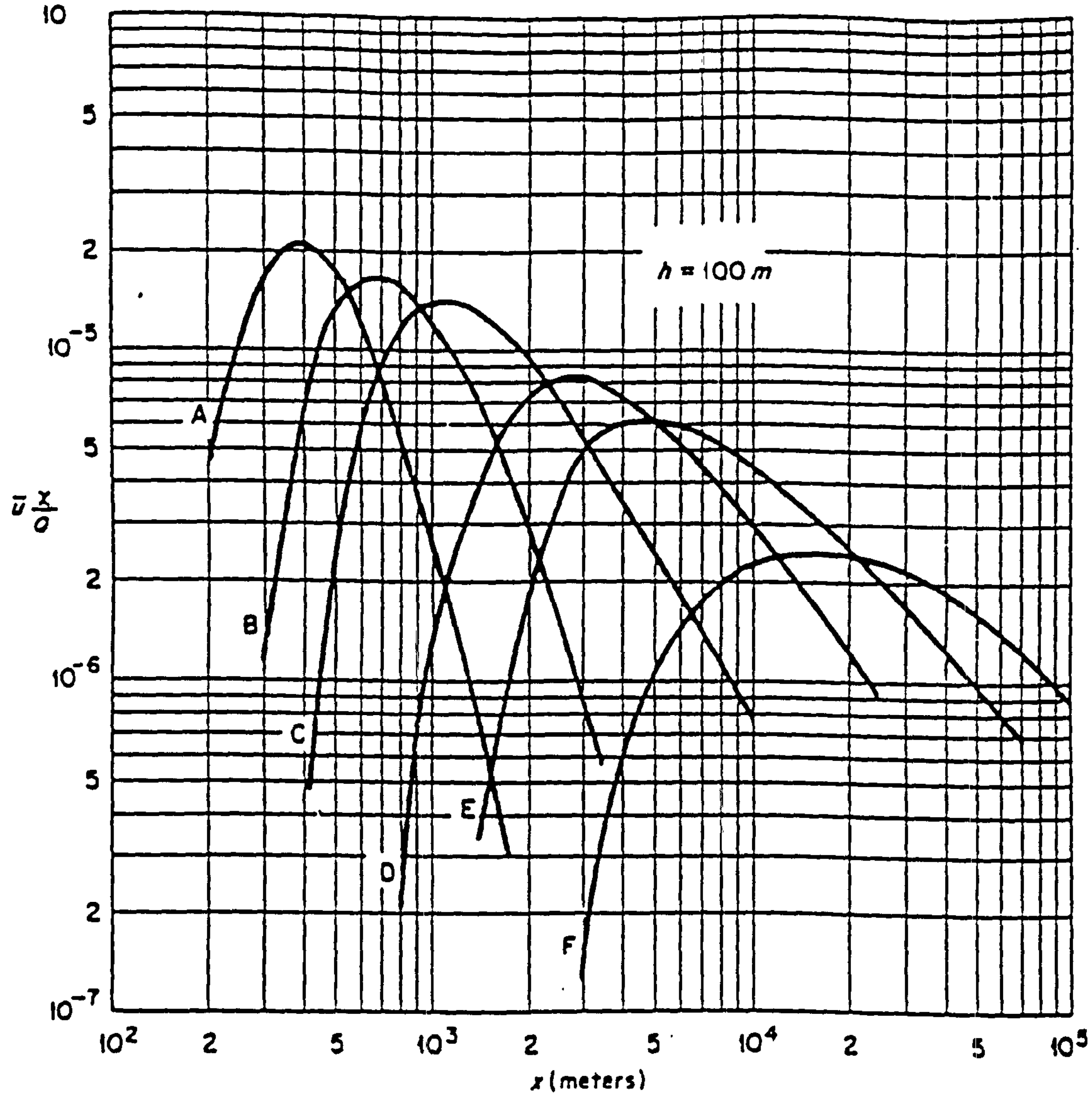


Figure 1: Values of the Normalized Dispersion Function ($\bar{u}\chi/Q$) as a Function of Downwind Distance, x, for a Release Height, h, of 100 m (From Hilsmeier et al., 1962)

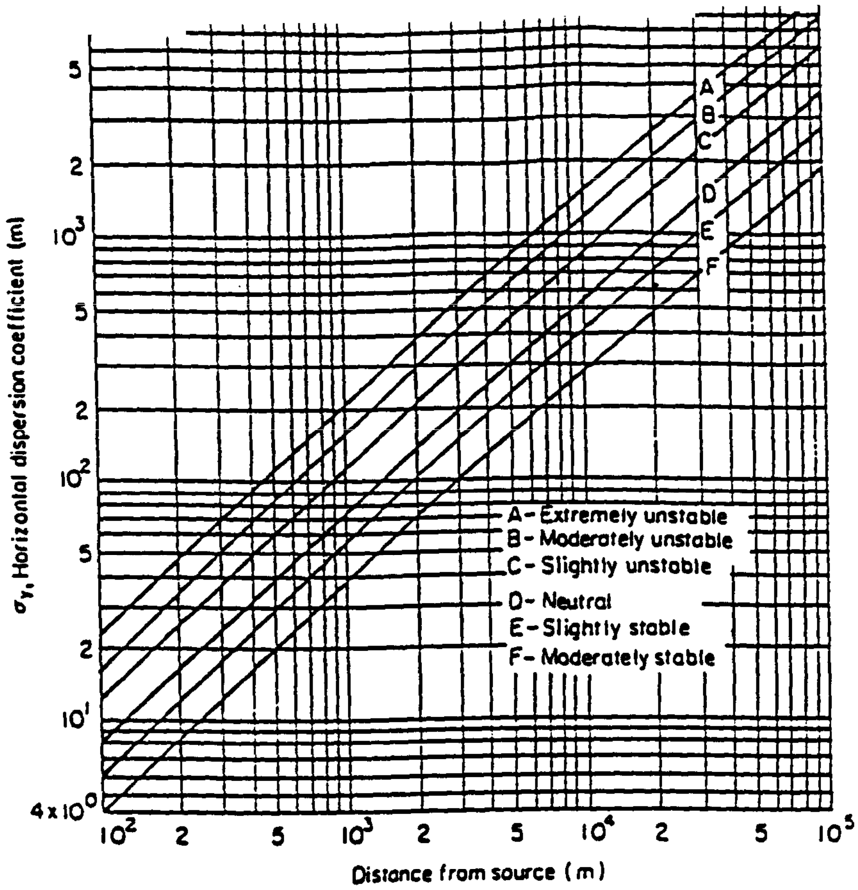


Figure 2: Lateral diffusion (σ_y) versus downwind distance from source for various turbulence types. [From Gifford (1968).]

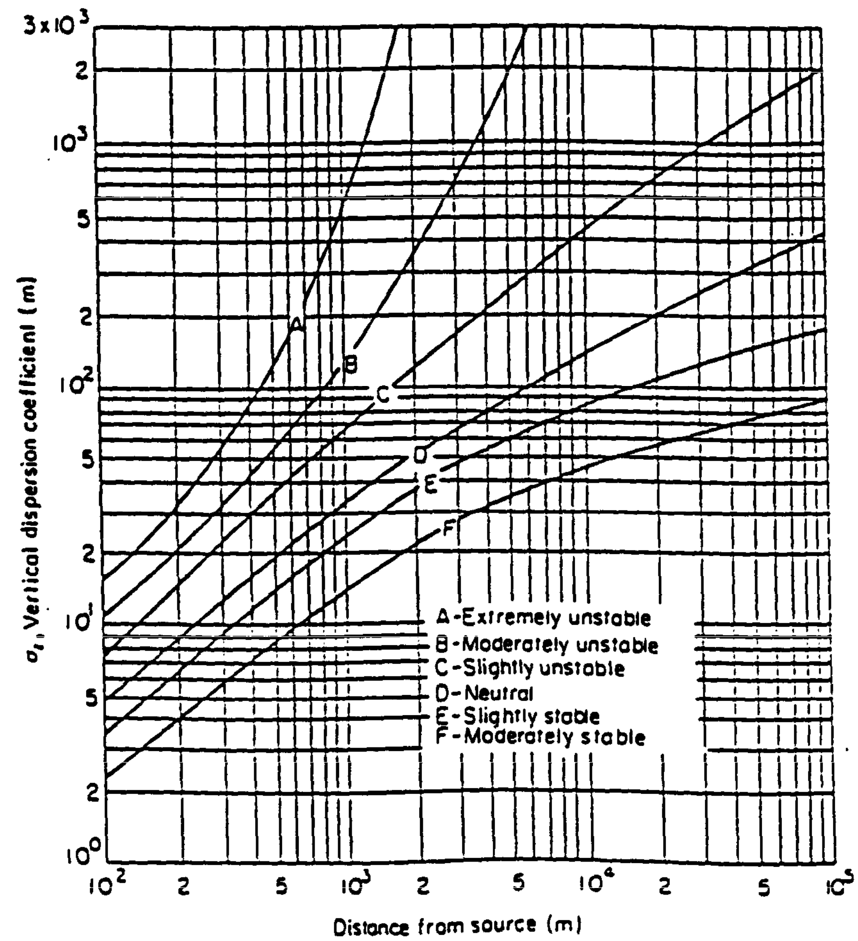


Figure 3: Vertical diffusion (σ_z) versus downwind distance from source for various turbulence types. [From Gifford (1968).]